The Vegetation on two Podzols on the Hornsby Plateau, Sydney

ROBIN A. BUCHANAN and G. S. HUMPHREYS

BUCHANAN, R. A., & HUMPHREYS, G. S. The vegetation on two podzols on the Hornsby Plateau, Sydney. *Proc. Linn. Soc. N.S.W.* 104 (1), (1979) 1980:49-71

Podzol soils on the upland sandstone plateaux in the Sydney Basin have received little attention and a characteristic vegetation on these soils has not been reported previously.

Two sites on the Hornsby Plateau are selected for detailed description of the understorey vegetation on these soils and the type of vegetative changes that occur across a podzol/non-podzol soil boundary. The two podzols are in topographically different situations, one on the plateau surface and one in a gully, but like all podzols in the area they occur in sand deposits which are usually present in areas of low slope. The vegetation on the podzols in both cases is similar and typical of that on most podzols of the dissected sandstone plateaux around Sydney.

Ceratopetalum gummiferum, because of its growth form and foliage, is usually the most conspicuous species on the podzols, even where it is not abundant. Other common species are *Banksia serrata, Xanthorrhoea arborea, Xylomelum pyriforme* and to a lesser extent *Gompholobium latifolium* and *Ricinocarpos pinifolius*. Plants growing on podzols usually have a wide habitat range or are species of the upper and middle gully slopes. Species typical of the plateau surface are usually absent or infrequent, even where the podzol immediately adjoins such a community. A combination of physiography (low slope depositional areas) and floristics can be used to locate these soils.

The woodland or open-forest on podzols is usually dominated by the widespread species *Angophora costata* and *Eucalyptus gummifera* and is usually taller than on surrounding soils. *Eucalyptus haemastoma* is extremely rare on podzols.

Robin A. Buchanan, 22 Alicia Road, Mt Kuring-gai, Australia 2080 (formerly *School of Biological Sciences, Macquarie University*) and *G. S. Humphreys, School of Earth Sciences, Macquarie University, North Ryde, Australia 2113;* *manuscript received 2 July 1979, accepted in revised form 19 September 1979.*

INTRODUCTION

A complex mosaic of vegetation is present on the deeply dissected, species-rich sandstone plateaux around Sydney. Because of this deep dissection, the flora can be grouped according to broad topographic situation with species most common on the plateau tops, on the slopes and in the gullies. The distribution of structural forms of the vegetation also follows a general topographic pattern, with variations in both species composition and structure influenced by aspect and climate (Pidgeon, 1937, 1938, 1941; Burrough, Brown and Morris, 1977).

However, many marked variations in the vegetation occur over distances of only a few metres and cannot be interpreted in terms of aspect, climate or macrotopography. Differences, although often minor, in soil properties and microtopography provide the best explanations of these changes. The rapid change in soil characteristics between a podzol and the neighbouring soil is a dramatic example of the sudden floristic change which can accompany a change in soil type.

Podzols in the Sydney region of New South Wales are well-known from the coastal dune sands and Nepean terraces (Burges and Drover, 1953; Walker and Hawkins, 1957; Walker, 1960). The podzols associated with the sandstone plateaux are at a higher topographic level and form a distinct third group, which previously has been given no more than cursory attention (Walker, 1960; Hamilton, 1976; Forster *et al.*, 1977).

An initial field survey on the sandstone plateau of Lambert Peninsula in Ku-ring-gai Chase National Park (Buchanan, 1980) showed that podzol soils occur in areas of quartz sand deposits. These deposits are 1-4 m thick and less than 5 ha in area and have accumulated in places of low slope either near the plateau surface or in gullies. The dark organically-stained upper-surface layer of the sand, 10-20 cm thick, lies on a conspicuously bleached layer, 30-50 cm thick. There is a sharp boundary against the underlying indurated pan. This pan is generally double with a brown 2-5 cm thick organic-stained layer over a 10-20 cm thick iron pan. As with most Australian podzols there is no "mor" horizon.

These podzol soils are associated with vegetation of distinctive floristic and structural characteristics. Well over fifty localities containing podzols on the sandstone plateaux around Sydney were then identified, using low slope areas, floristics and vegetation structure as search criteria. The soil type was confirmed from pits and/or auger holes. Two of these sites on the Hornsby Plateau have been chosen for detailed description of the understorey vegetation on the podzols and the type of vegetative changes that occur across a podzol/non-podzol soil boundary. The vegetation characteristics of these podzols have not been reported previously.

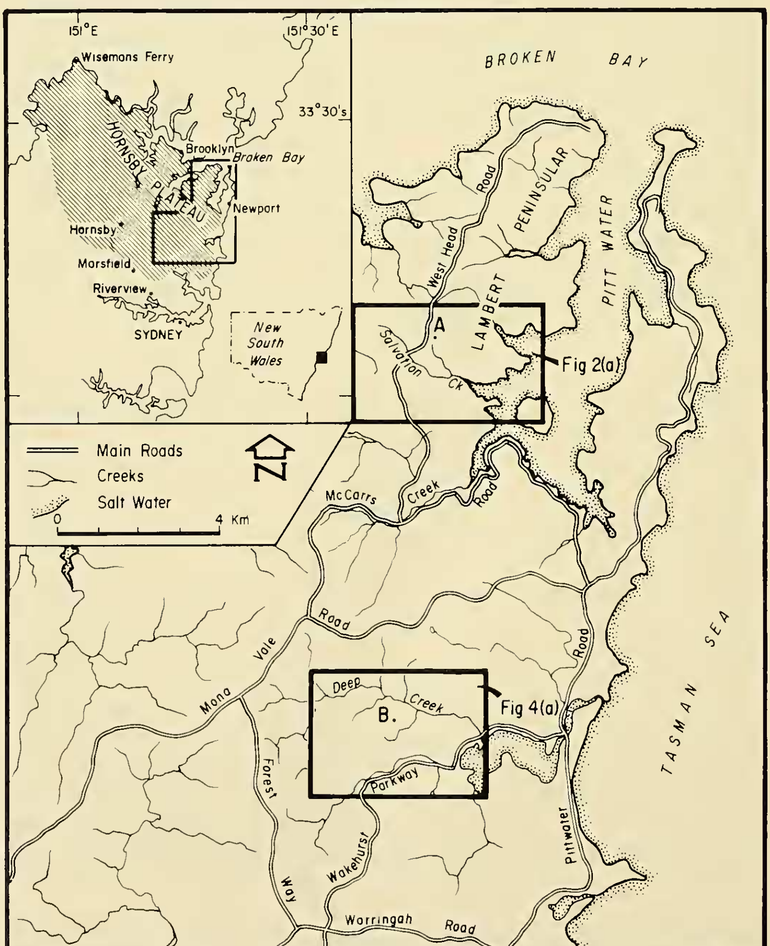

Fig. 1. Locations of the study areas.

SITE DESCRIPTION

The Hornsby Plateau (Fig. 1) is an undulating dissected surface which slopes gently from an elevation of approximately 210 m above Broken Bay in the north to about 120 m in the south about Port Jackson. It consists mostly of the near-horizontally bedded Hawkesbury Sandstone, a sequence of Triassic quartzose sandstones with minor interbedded shale units. It is underlain by rocks of the Narrabeen Group, which outcrop along the north-eastern corner of the Plateau, and is capped in places by remnants of the Wianamatta shale. Meteorological data (Bureau of Meteorology, 1948, 1975) for five stations on or near the Hornsby Plateau are summarized in Table 1.

Site A is in Ku-ring-gai Chase National Park and it is one of twenty-eight podzols in the Lambert Peninsula and McCarrs Creek area. The podzol is in a shallow, basin-shaped catchment. This catchment is located on the plateau surface at 135 m above sea level (a.s.l.) with abrupt rises to 229 m in the north-west and 200 m in the north-east (Figs 1 & 2).

The sand deposit in which the podzol has formed covers approximately 2 ha and is divided by two major creeks (Figs 2b & 3a). The channel of the larger creek has been filled to a depth of about 2 m with layers of iron-rich organic sludge and sand (Fig. 3b). The fill supports a swamp of dense *Gahnia sieberana* and *Empodisma minus* (syn. *Calorophus minor*) with other such species such as *Banksia robur* interspersed.

This sand body is divisible into two units, with the largest section surrounding the northern part of the swamp. This section contains discontinuous podzol development, while the smaller section along the western side of the swamp has a near-continuous, well-developed podzol (Fig. 3a).

TABLE 1

A summary of meteorological data for stations [1] on or near the Hornsby Plateau

Station	Rainfall (mm) Yearly total of means	Rain days Number Yearly total of means	Daily Max Temp (°C) Yearly Mean	Daily Min Temp (°C) Yearly Mean
Marsfield[2] (33°47'S, 151°7'E) 45.7 m a.s.l.	1178	153	22.4	11.1
Riverview[2] (33°50'S, 151°10'E) 22.9 m a.s.l.	928	120	22.9	12.2
Brooklyn[3] (33°33'S, 151°13'E) 5 m a.s.l.	1279	98	—	—
Hornsby[3] (33°42'S, 151°06'E) 183 m a.s.l.	1237	99	—	—
Newport[3] (33°39'S, 151°19'E) 5 m a.s.l.	1195	113	—	—

1. : The location of these stations is shown on Fig. 1
2. : Bureau of Meteorology (1975)
3. : Bureau of Meteorology (1948)

From the edge of the sand body to the creek there is a steep slope (approximately 10-18°) and in many places along this slope the podzol pan is revealed at the surface. On the sand body proper the slope is gentle and rarely exceeds 4°. The section across the swamp and podzol (Fig. 3b) shows the sand deposit as a crest 4-5 m high between the swamp and an intermittent drainage line. Further north, in the area where the vegetation was sampled, no change in slope occurs at the sharp boundary between the non-podzolized, yellow-brown sands (non-podzol) and the podzol (Figs 3b & 10). A description of these soil types is given in Appendix 1.

The podzol supports a woodland (Specht, 1970) of *Eucalyptus gummifera, Angophora costata* and *E. piperita*, while the non-podzol that surrounds the podzol/swamp complex supports a low woodland to woodland mostly dominated by *Eucalyptus haemastoma, E. oblonga, E. gummifera* and *E. sieberi. Ceratopetalum gummiferum* is a conspicuous understorey species on the podzol.

Site B is located towards the southern margin of the deeply incised Deep Creek

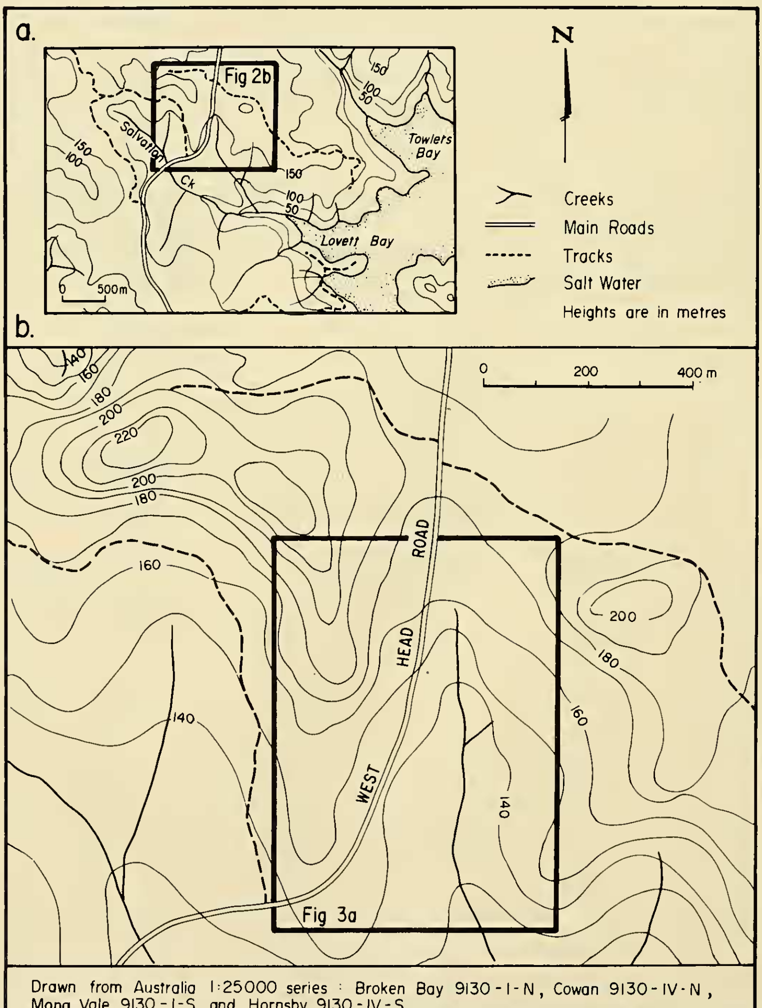

Fig. 2. Site A. (a) an enlargement from Fig. 1. (b) an enlargement of (a).

catchment (Fig. 1). The site (57 m a.s.l.) is within a small basin surrounded by steep, sandstone-benched slopes which rise more than 100 m a.s.l. towards the west. The basin drains eastward into one of the main tributaries of Deep Creek (Fig. 4). A quartz sand deposit up to 4 m deep occurs within the basin and has a general surface slope of 2-3° to the east. The basin is drained by two intermittent streams, of which the more northerly one has trenched into the sand deposit along its northern margin to a depth of 3 m. (Fig. 5).

A podzol is developed in the central thicker portion of the sand body and covers 0.15 ha (Fig. 5a). There is an abrupt boundary between the central podzol and the surrounding non-podzolized, yellow-brown sands (Appendix 1).

The podzol supports a woodland of *Angophora costata, Eucalyptus gummifera* and *E. globoidea*, while the surrounding non-podzol has a low woodland of *E.*

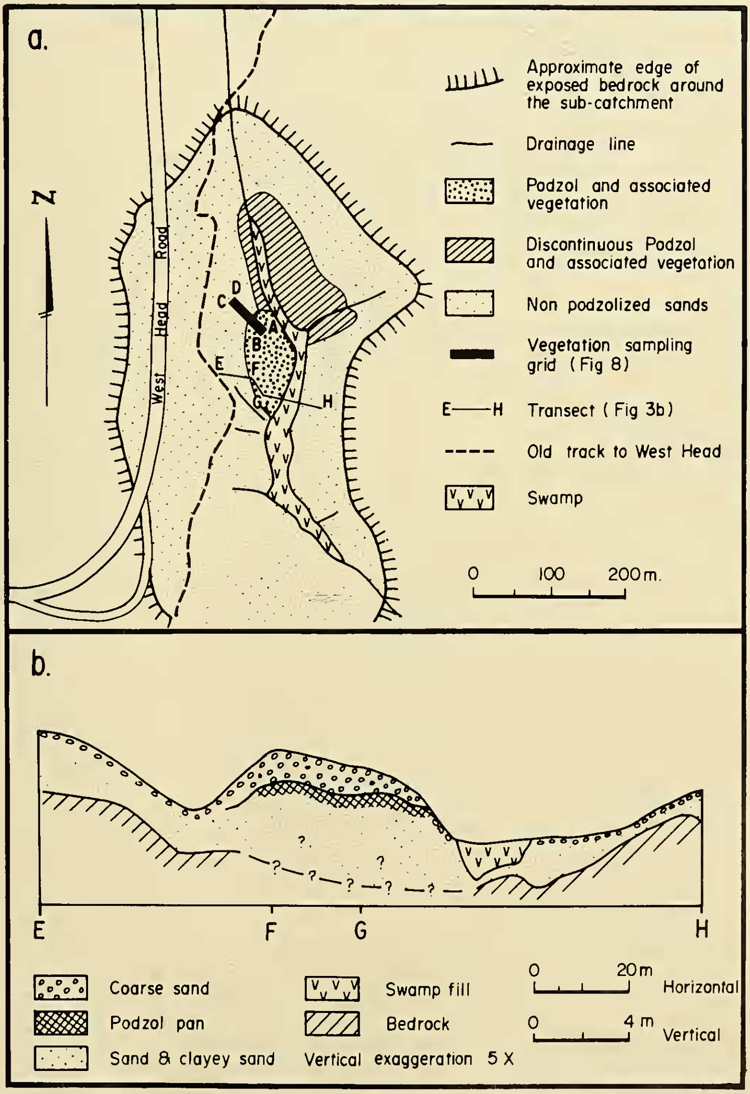

Fig. 3. Site A. (a) an enlargement from Fig. 2. (b) transect across the podzol and its surroundings.

haemastoma, E. gummifera and *E. globoidea. Ceratopetalum gummiferum* is again a conspicuous understorey shrub on the podzol.

Methods

FIELD METHODS

Soils. The depth of the podzol pan and the lateral extent of the podzol were determined from trenches, auger holes and by probing with a 7 mm diameter steel rod. The pan could be distinctly felt with the rod. At Site B a detailed examination of

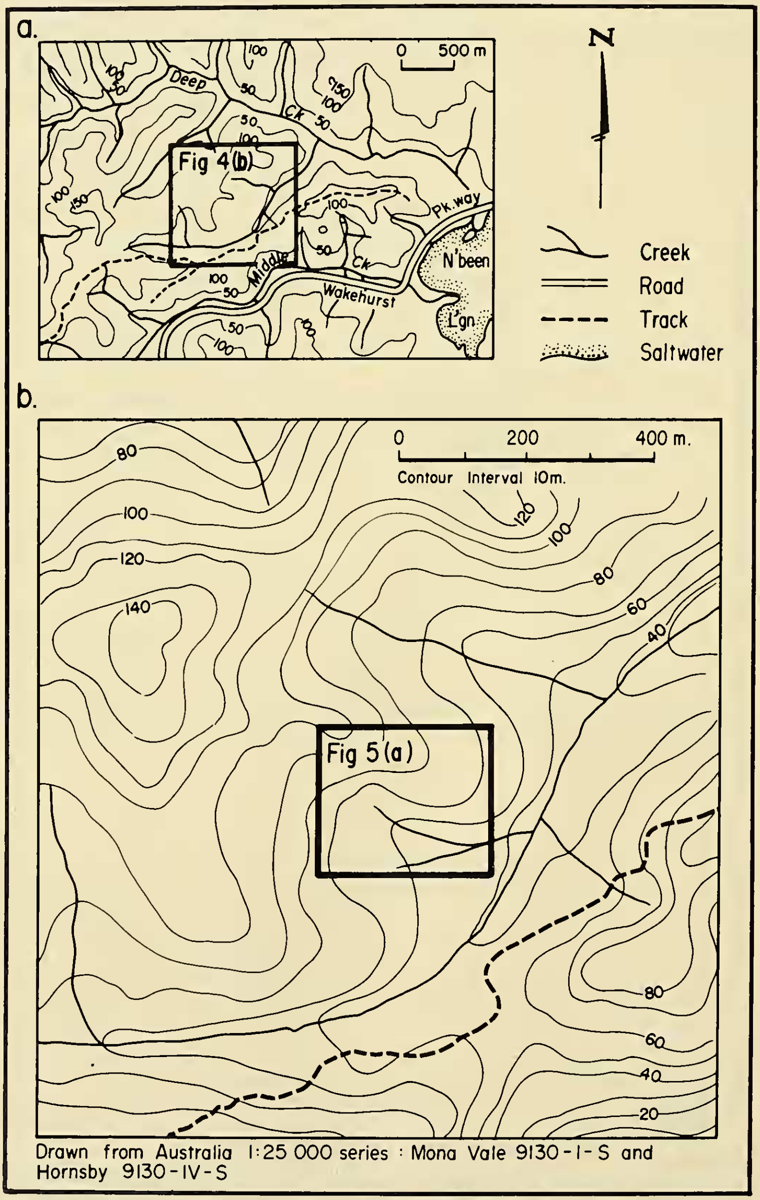

Fig. 4. Site B. (a) an enlargement from Fig. 1. (b) an enlargement of (a).

the soils was carried out and a description of the podzol and non-podzol soils from this site is given in Appendix 1.

Vegetation. Trees were not sampled as they were in insufficient numbers on the well-developed podzol at both sites to give statistically significant results. The shrub layer was sampled using 100 circular quadrats, area 2 m^2, set out in a rectangular grid with the longer side at right angles to the abrupt soil boundary. Half the grid and thus half the quadrats were on each soil. The distance between the centres of the quadrats was 3 m in the columns arranged parallel to the longer sides and 2 m in the rows parallel to the soil boundary. At Site A the grid consisted of five columns and twenty rows. At Site B it consisted of seven columns and fourteen rows, with an extra quadrat added to the

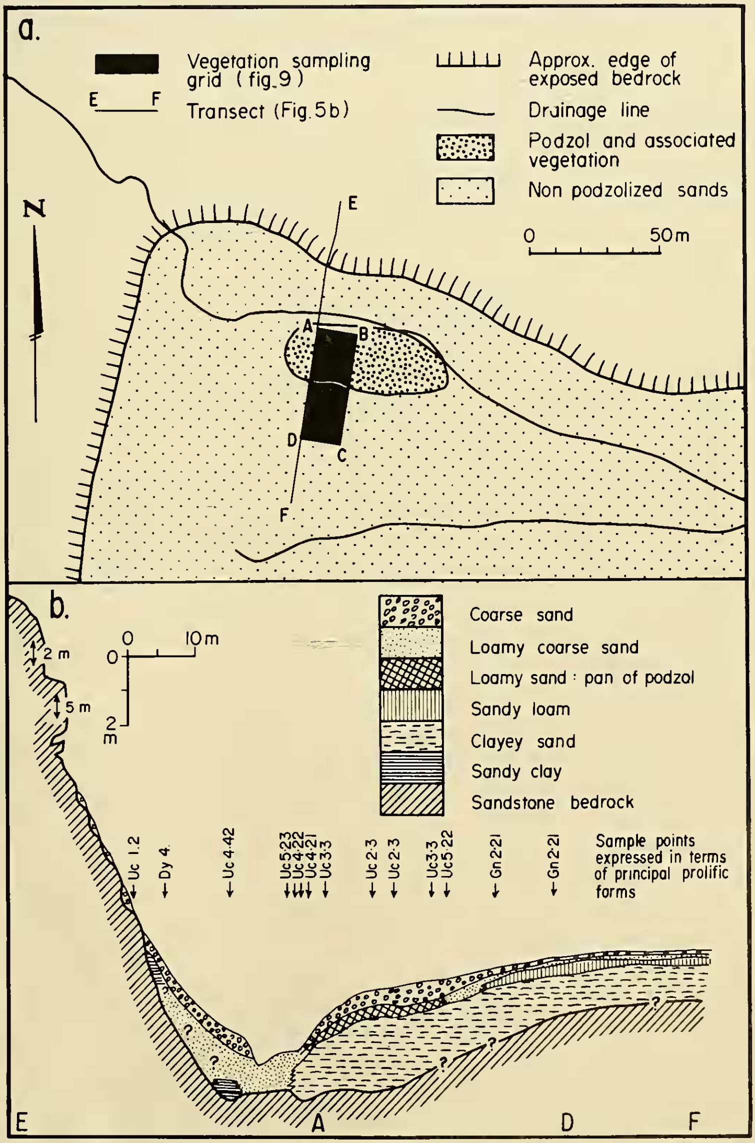

Fig. 5. Site B. (a) an enlargement from Fig. 4 b. (b) transect across the podzol and its surroundings.

podzol and non-podzol to give a total of 100 quadrats. The variation in the grid pattern was dictated by the size and shape of the podzols. Row numbers are shown on Figs 10 & 11.

The small quadrat size was chosen to facilitate sampling of the small understorey species. All dicotyledon and gymnosperm stems rooted in the quadrats and with a diameter of 4-100 mm 20 cm from the ground, were measured to the nearest millimetre. The height of each stem was estimated to the nearest 0.5 m. The monocotyledons *Xanthorrhoea arborea* and *X. media* were only recorded as present at Site A, but at Site B the number of individuals of this genus was recorded also.

TREATMENT OF DATA

In order to reduce some of the minor variation in the data, species occurring in less than 5% of the total number of quadrats at each site were excluded from the relative importance calculations and the association and principal component analyses.

Relative Importance and Exclusiveness. The frequency, density (Kershaw, 1973), average basal area and average height were calculated for each species on each soil at both sites (Tables 2 & 3). The relative importance value (RIV) for each species was obtained by summing the relative density, relative frequency, relative dominance (Kershaw, 1973), and the relative height to give a total out of 400. The relative height was calculated by:

$$\frac{\text{height of sp. on a particular soil}}{\Sigma \text{ height of all spp. on a particular soil}} \times 100$$

The RIV is similar to the "importance value" used by Curtis and McIntosh (1950). Relative height was added to give a better balance between size (dominance and height) and numbers (frequency and density).

The exclusiveness value is defined as:

$$\frac{\text{number of quadrats in which species A occurred on a particular soil}}{\text{number of quadrats in which species A occurred}}$$

and was calculated for the soil on which the species was most frequent. It is a measure of the degree to which a species is restricted to a particular soil in the sampled area. Species with an exclusiveness value of greater than 85% were assigned to the soil where they were most frequent.

All species mentioned are listed in Appendix 2.

Principal Component Analysis. Each quadrat was weighted by RIVs obtained by summing the relative density, relative dominance and the relative height of each species. The resulting RIV data for the spp. within the quadrats were subjected to principal component analysis, using a programme based on the BMDOIM programme of Dixon (1973). The small quadrat size ensured maximum variability (Table 4) and the plot of these results is not included. The quadrats were then grouped into rows parallel to the soil boundary, the RIV, also including relative frequency, was calculated for each species, and the data were then re-analysed (Table 5).

Association Analysis. The normal and inverse association analyses were applied to the data using the DIVINFRE program of the CSIRO Division of Land Research, Canberra (see Williams, 1976, p.94). This is a divisive monothetic analysis based on presence/absence data. The program was terminated at the five group level, as it was more than sufficient to show the difference in the vegetation on the podzol and non-podzol. The inverse analysis added little to the information included in Tables 2 & 3

TABLE 2

Frequency, density, average basal area, average height, relative importance value (RIV) and exclusiveness of species on the podzol (P) and non-podzpol (N-P) at Site A.

Species	Frequency (%) P	Frequency (%) N-P	Density No/100m² P	Density No/100m² N-P	Av. basal area (cm²) P	Av. basal area (cm²) N-P	Av. height (½ m) P	Av. height (½ m) N-P	RIV (400) P	RIV (400) N-P	Exclusiveness	
†*Xanthorrhoea arborea*	30	0	—	0	—	0	—	—	—	—	100	Podzol species
**Pimelea linifolia*	4	0	3	0	0.3	0	1	0	—	—	100	
**Angophora costata*	2	0	1	0	26.4	0	5	0	—	—	100	
**Eucalyptus piperita*	2	0	1	0	2.3	0	1.5	0	—	—	100	
Ceratopetalum gummiferum	66	0	184	0	6.0	0	2.5	0	152	0	100	
Gompholobium latifolium	16	0	29	0	0.8	0	2.0	0	14	0	100	
Xylomelum pyriforme	10	0	14	0	3.8	0	0.5	0	9	0	100	
Phyllota phylicoides	42	2	93	3	0.4	0.6	1.0	1.0	35	2	95	
Ricinocarpos pinifolius	42	4	118	2	0.5	0.4	1.0	1.0	42	2	91	
Acacia suaveolens	34	4	25	2	0.8	1.8	2.0	2.0	17	2	89	
A. terminalis	18	2	10	1	1.9	0.9	2.5	2.0	9	1	90	
A. ulicifolia	16	2	13	1	0.8	4.9	1.5	3.0	8	1	99	
Boronia pinnata	22	8	47	9	0.3	0.2	1.0	1.0	18	5	73	Common species
Hibbertia linearis	36	22	23	25	0.4	0.5	1.0	1.0	15	14	62	
Leucopogon ericoides	34	28	61	38	0.3	0.3	1.5	1.0	25	20	55	
Dillwynia retorta	20	20	14	13	0.6	0.5	1.5	1.5	9	10	50	
Platysace linifolia	6	8	3	11	0.1	0.3	0.5	1.0	2	6	57	
Banksia serrata	26	30	31	23	5.0	15.6	1.0	1.5	23	56	54	
†*Xanthorrhoea media*	30	40	—	—	—	—	—	—	—	—	57	
Leptospermum attenuatum	22	50	48	108	0.8	1.8	1.0	1.0	18	68	69	
Lambertia formosa	2	16	5	54	0.9	0.7	1.0	1.0	2	27	89	Non-Podzol species
Petrophile pulchella	2	50	1	61	1.1	1.0	2.0	1.5	1	45	96	
Epacris pulchella	0	40	0	32	0	0.2	0	1.0	0	20	100	
Leucopogon microphyllus	0	32	0	30	0	0.2	0	1.0	0	17	100	
Banksia spinulosa	0	24	0	34	0	1.5	0	1.5	0	25	100	
Grevillea sericea	0	20	0	15	0	1.1	0	1.5	0	12	100	
Pultenaea elliptica	0	18	0	31	0	0.4	0	1.5	0	18	100	
Gompholobium grandiflorum	0	16	0	21	0	0.3	0	1.0	0	11	100	
Epacridaceae sp.	0	12	0	14	0	0.2	0	0.5	0	7	100	
Acacia myrtifolia	0	10	0	9	0	0.4	0	1.0	0	6	100	
Grevillea buxifolia	0	10	0	9	0	2.6	0	2.0	0	9	100	
Eucalyptus gummifera	0	10	0	5	0	18.9	0	2.5	0	15	100	
**Boronia ledifolia*	0	8	0	4	0	0.2	0	1.0	—	—	100	
**Hakea gibbosa*	0	8	0	4	0	1.8	0	2.5	—	—	100	
**H. dactyloides*	0	8	0	24	0	0.7	0	1.5	—	—	100	
**Eucalyptus* sp.	0	8	0	7	0	1.5	0	1.0	—	—	100	
**Leptospermum flavescens*	0	6	0	4	0	1.2	0	1.5	—	—	100	
**Woollsia pungens*	0	6	0	3	0	0.4	0	1.0	—	—	100	
**Lomatia silaifolia*	0	6	0	8	0	0.2	0	0.5	—	—	100	
**Persoonia levis*	0	6	0	5	0	1.1	0	1.0	—	—	100	
**P. lanceolata*	0	4	0	3	0	0.5	0	1.0	—	—	100	
**Banksia aspleniifolia*	0	4	0	3	0	0.5	0	1.0	—	—	100	
**Eucalyptus haemastoma*	0	4	0	2	0	1.0	0	2.0	—	—	100	
**Leptospermum squarrosum*	0	2	0	1	0	2.0	0	1.0	—	—	100	
**Persoonia* sp.	0	2	0	1	0	1.0	0	1.5	—	—	100	
**Bossiaea heterophylla*	0	2	0	1	0	0.1	0	1.0	—	—	100	
‡Overall average					2.2	1.7	1.5	1.0				

†Monocotyledons: not included in RIV calculations
*Species that occurred in less than 5% of all the quadrats: not included in RIV calculations
‡The overall average does not include species marked*

TABLE 3

Frequency, density, average basal area, average height, relative importance value (RIV) and exclusiveness of species on the podzol (P) and non-podzol (N-P) at Site B.

Species	Frequency (%)		Density No/100m²		Av. basal area (cm²)		Av. height (½ m)		RIV (400)		Exclu-siveness
	P	N-P	P	N-P	P	N-P	P	N-P	P	N-P	
Podzol species											
†*Xanthorrhoea arborea*	24	0	13	—	—	—	—	—	—	—	100
†*X. media*	16	0	8	0	—	—	—	—	—	—	100
**Dodonaea triquetra*	8	0	10	0	0.7	0	2.0	0	—	—	100
**Grevillea linearifolia*	6	0	9	0	1.3	0	2.5	0	—	—	100
**Xylomelum pyriforme*	6	0	5	0	1.6	0	1.0	0	—	—	100
Podocarpus spinulosus	42	0	41	0	0.2	0	0.5	0	21	0	100
Ceratopetalum gummiferum	30	0	35	0	8.0	0	3.5	0	55	0	100
Gompholobium latifolium	16	0	33	0	0.6	0	2.0	0	24	0	100
Ricinocarpos pinifolius	10	0	42	0	0.3	0	1.5	0	24	0	100
Common species											
**Leucopogon ericoides*	4	2	11	3	0.2	0.2	1.0	1.0	—	—	67
**Angophora costata*	4	2	2	1	2.5	5.7	3.0	4.0	—	—	67
Woollsia pungens	22	16	18	10	0.5	0.4	2.0	2.0	14	9	58
Banksia serrata	16	14	11	12	19.9	7.0	1.5	1.5	30	19	53
Dillwynia retorta	72	64	145	76	0.9	0.6	2.5	2.5	94	45	53
Hibbertia sp.	8	8	4	4	0.5	0.5	1.5	1.5	7	4	50
Eriostemon australasius	18	18	15	11	0.3	0.2	2.5	1.5	16	8	50
Petrophile pulchella	22	24	14	21	2.1	1.1	3.0	2.5	16	9	52
Acacia suaveolens	18	20	12	14	0.4	1.0	1.0	2.5	14	12	53
Grevillea buxifolia	4	6	2	5	4.0	1.0	3.5	2.5	3	5	60
Eucalyptus gummifera	6	10	6	7	29.1	23.7	5.0	4.0	23	22	63
E. sp.	2	4	1	2	22.9	9.9	5.0	2.5	—	—	67
Acacia terminalis	4	8	2	4	9.7	12.1	4.5	4.4	6	16	67
Leptospermum attenuatum	28	62	22	55	5.8	8.9	3.0	2.5	32	73	69
Non-Podzol species											
Banksia marginata	16	96	11	127	0.8	0.7	2.5	2.0	11	68	86
Phyllota phylicoides	4	28	4	46	0.3	0.4	1.5	1.0	3	23	88
Banksia ericifolia	2	18	1	13	21.3	8.6	4.0	3.0	4	21	90
Hakea gibbosa	4	34	3	23	3.8	2.9	3.5	3.0	6	22	89
Platysace linearifolia	0	20	0	20	0	0.4	0	2.0	0	14	100
Lambertia formosa	0	12	0	26	0	1.1	0	1.0	0	13	100
Grevillea sericea	0	12	0	6	0	0.5	0	2.0	0	7	100
Hakea teretifolia	0	10	0	5	0	2.3	0	3.5	0	8	100
**Pultenaea* sp.	0	4	0	2	0	0.1	0	2.0	—	—	100
**Hakea dactyloides*	0	4	0	2	0	2.6	0	2.4	—	—	100
**Kunzea capitata*	0	2	0	1	0	0.5	0	3.5	—	—	100
**Leptospermum* sp.	0	2	0	1	0	0.3	0	2.0	—	—	100
**Conospermum longifolium*	0	2	0	1	0	0.6	0	2.0	—	—	100
**Pultenaea elliptica*	0	4	0	4	0	0.6	0	2.5	—	—	100
‡Overall average					2.6	2.3	2.5	2.5			

†Monocotyledons: not included in RIV calculations

*Species that occurred in less than 5% of all the quadrats: not included in RIV calculations

‡The overall average does not include species marked*

and it is not presented in the results. All computations were run on a UNIVAC 1100 computer at Macquarie University.

Results

TABLES 2 AND 3

When species with an exclusiveness value of greater than 85% were assigned to the soil where they were most frequent, three distinct groups which were readily visible in the field resulted: podzol species, species common to both soil types, and non-podzol species. This classification applies only to the sampled areas, as none of the podzol species is restricted regionally to this soil.

The ratio of these three groups (podzol: common: non-podzol) for the full species list at Site A is 1.5 : 1 : 3.25. Not only is the group of species common to both soils the smallest, but it also contributes only a quarter to the total RIV on the podzol and slightly less than half on the non-podzol. At the more sheltered, moister Site B the podzol group is the smallest, with the common and non-podzol groups the same size (1 : 1.5 : 1.5). At this site the group of species present on both soils contributes well over half to the RIV total on the podzol and slightly over a half on the non-podzol.

Vegetation on the Podzol. The species locally restricted to the podzol and present at each site are *Ceratopetalum gummiferum, Ricinocarpos pinifolius, Gompholobium latifolium, Xylomelum pyriforme* and *Xanthorrhoea arborea.*

At Site A, *C. gummiferum* is the principal species on the podzol. This single species contributes 70% of the summed values for the basal area, 40% for height, 26% for density and 16% for frequency to give a total score of 152 out of 400. The next two most important plants on this soil, *R. pinifolius* (RIV 42) and *Phyllota phylicoides* (RIV 35), attain a score of less than a third of that for *C. gummiferum.* Although these two podzol species are quite common, their small size makes them a less important and less conspicuous part of the flora.

At Site B there is no clear principal species on the podzol. A species common to both soils, *Dillwynia retorta*, has a score of only 94, with *C. gummiferum* reaching a value of over half this score at 55. Another species common to both soils, *Leptospermum attenuatum*, is the third most important species (RIV 32). The regionally less-common species *Podocarpus spinulosus* is confined to the podzol at Site B where it is the second most frequent species.

C. gummiferum is less important at the more sheltered Site B than at Site A even though it is usually found in moist, sheltered places. At Site B the plants were larger (average height and basal area 3.5 m and 8 cm^2 respectively) than at Site A (average height and basal area 2.5 m and 6 cm^2) but only 35 stems were recorded at Site B compared with 184 stems at Site A. This difference may be caused by a lower fire

TABLE 4

Principal component analysis, in quadrats (100) of vegetation RIV data: table of components and their respective eigenvalues

site	component	eigenvalue	% variance accounted for	cumulative variance %
A	1	2.5169	9	9
	2	1.9165	7	16
	3	1.6483	7	23
	4	1.4765	5	28
	5	1.4134	5	33
	6	1.3181	5	38
	7	1.2825	5	43
	8	1.1935	4	47
B	1	2.2376	10	10
	2	1.6529	7	17
	3	1.5981	7	24
	4	1.5219	6	30
	5	1.4715	7	37
	6	1.3452	6	43
	7	1.1847	5	48
	8	1.1707	5	53

frequency, as plants in fire-prone areas tend to have larger numbers of smaller shoots than plants in less fire-prone areas.

P. phylicoides is the only species that grows on the opposite soil at each site but a few species are confined to one soil at one site and common to both soils at the other.

Vegetation on the Non-podzol. A species common to both soils, *L. attenuatum*, is the most important species on the non-podzol at both sites.

At Site A there is no predominant species on the non-podzol. *L. attenuatum* and another species common to both soils, *Banksia serrata,* are the most important species with RIV totals of 68 and 56 respectively, while the non-podzol species, *Petrophile pulchella*, has a score of 45. There are a large number of infrequent non-podzol species at this site.

At Site B, *L. attenuatum* has a RIV of 73. The next most important species, *Banksia marginata*, is mostly restricted to this soil and has a score of 68, while another species common to both soils, *Dillwynia retorta,* has a RIV of 45. *B. marginata* has a very high frequency (98%) and is therefore a conspicuous species on this soil even though its RIV is not large.

PRINCIPAL COMPONENT ANALYSIS

The first component of the row analysis accounted for over 30% of the variability and with the second component over 40% at both sites (Table 5) with the first component representing the change in soil type.

The Site A analysis shows three groups (Fig. 6), the podzol group and two groups on the non-podzol. The two podzol border rows, nine and ten, are included within the podzol group but the non-podzol border rows, eleven, twelve and thirteen, lie midway between the podzol group and the other non-podzol rows along the first component. In these three rows, species common to both soils are important ingredients and many of the non-podzol species are absent. Within the non-podzol group there is a gradation from rows fourteen to twenty along the second component. This may relate to drainage and slope.

At Site B the podzol group is split into two sub-groups, with the two rows on the steeper slope adjacent to the creek well separated from the other podzol rows along the

TABLE 5

Principal components analysis, in rows, of vegetation RIV data: table of components and their respective eigenvalues

site	component	eigenvalue	% variance accounted for	cumulative variance %
A	1	8.5464	32	32
	2	3.0693	11	43
	3	2.5654	10	53
	4	2.3691	8	61
	5	1.7961	7	68
	6	1.5891	6	74
	7	1.5119	5	79
	8	1.3026	5	84
B	1	7.0695	31	31
	2	3.1869	14	45
	3	2.9750	13	58
	4	2.2209	9	67
	5	1.8840	8	75
	6	1.7358	8	83
	7	1.4994	6	89
	8	0.6869	3	92

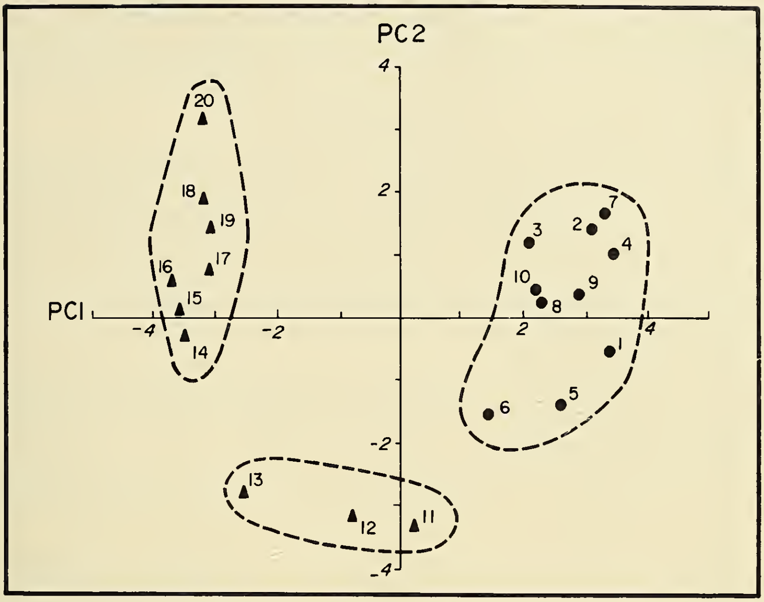

Fig. 6. Site A. Plot of the 1st x 2nd principal component scores of the twenty rows. The location of rows is shown on Fig. 10.
• Podzol row ▲ Non-podzol row.

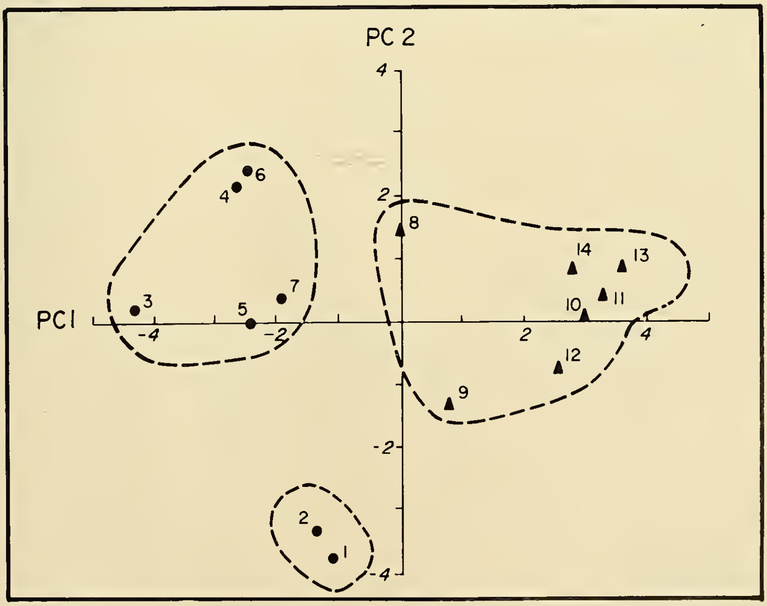

Fig. 7. Site B. Plot of the 1st x 2nd principal component scores of the fourteen rows. The location of rows is shown on Fig. 11.
• Podzol row ▲ Non-podzol row.

second component (Fig. 7). In both rows, two out of the three most important species are common to both soils but these rows contain the only intrusion of a non-podzol species, *Hakea gibbosa*. Podzol species such as *C. gummiferum* and *R. pinifolius* are also present and the mixture of podzol and non-podzol species guaranteed that these two rows would be plotted well away from the main groups.

The podzol border rows, six and seven, are within the main podzol group but the two non-podzol border rows, eight and nine, lie between the podzol and non-podzol groups along the first component. As for Site A, the non-podzol border rows are dominated by species common to both soils, while many non-podzol species are absent. Although the podzol and non-podzol plot out as two distinct groups there is a rough ordering from rows three to fourteen along the first component.

NORMAL ASSOCIATION ANALYSIS

The first two divisions in the normal association analysis at Site A define the podzol vegetation, while at Site B the first division basically divides the vegetation into podzol and non-podzol (Figs 8 & 9).

The community maps (Figs 10 and 11) show that only 6% of the quadrats at Site A and 10% of the quadrats at Site B do not conform to the soil groups. Even this small amount of non-conformity seems to be the result of the highly artificial classification system, as the chance occurrence of one species in a quadrat can dictate its final grouping. When the relative importance values of the species are considered most of

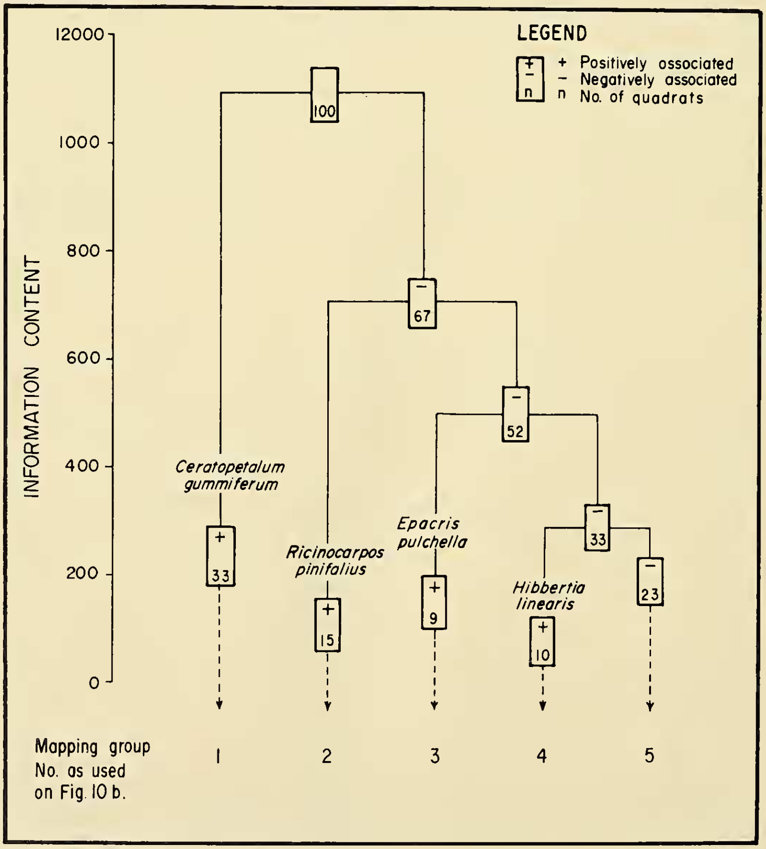

Fig. 8. Site A. Normal association analysis.

these apparent discrepancies disappear. Even the well-defined finger of non-podzol vegetation that intrudes into the podzol on the Site B community map is the intrusion of a single species, *B. marginata.* This species is unimportant in these quadrats.

Discussion

All results, whether those of the exclusiveness calculations, the association analysis or the principal components analysis, showed that there was a difference in the vegetation on the podzol and the non-podzol soils at each site. This difference was less evident at the moister, more sheltered Site B than at the plateau site, Site A. At Site B there were more species common to both podzol and non-podzol soils, and these species were more important than at Site A. The vegetation characteristic of the podzol soil is present to the podzol boundary where it ceases abruptly. At both sites, on the non-podzol soil the vegetation close to the soil junction is dominated by species common to both soils, with many of the non-podzol species being infrequent. Though the two podzol sites differ in topographic terms, the vegetation on both podzols looks remarkably similar. Extensive field reconnaissance within the Sydney Basin has shown that the vegetation on these two sites is typical of most podzols on the sandstone plateaux.

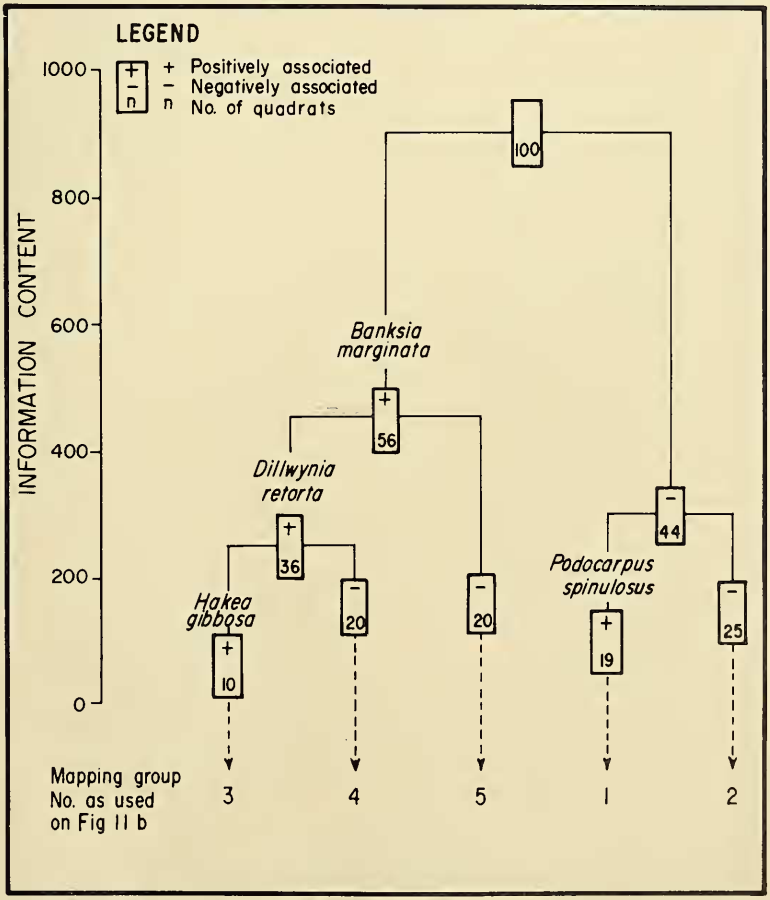

Fig. 9. Site B. Normal association analysis.

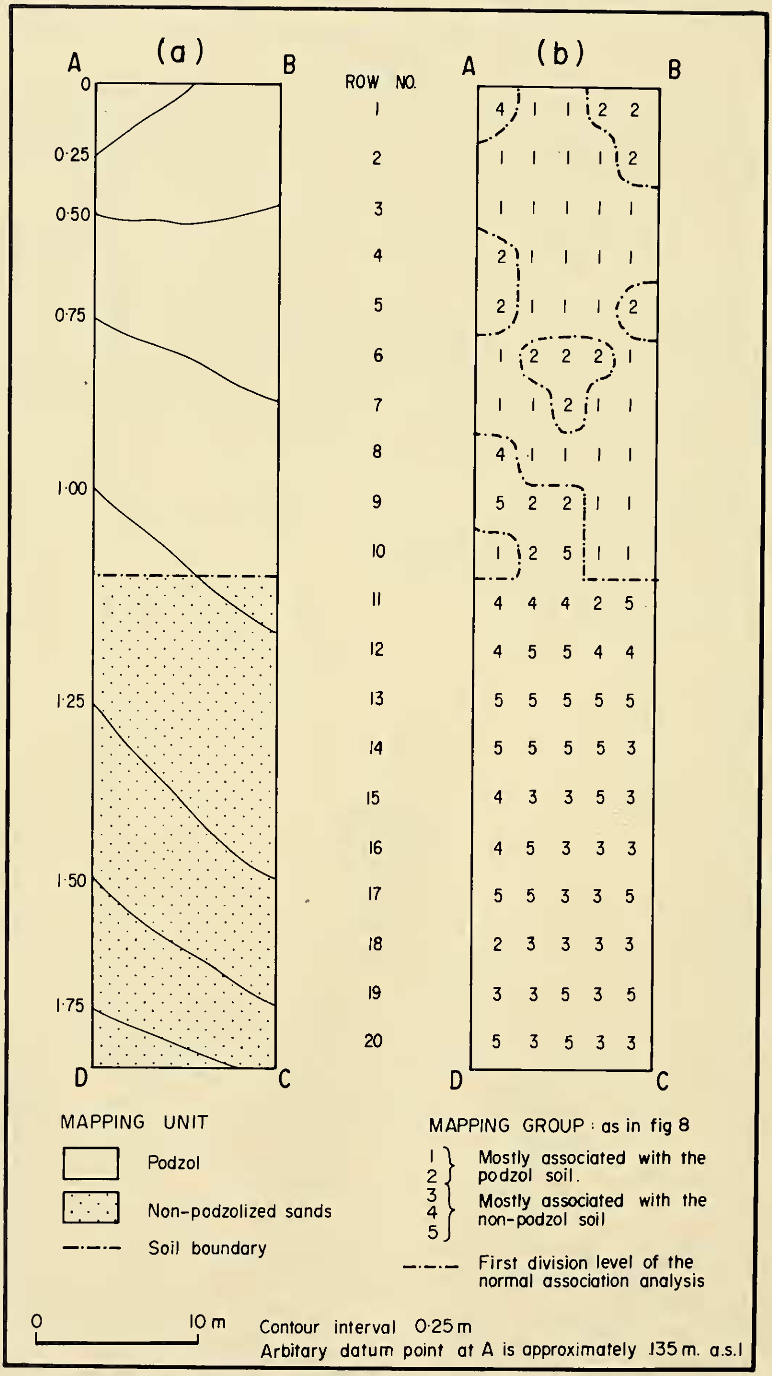

Fig. 10. Site A. (a) Soil and microtopography of the sample grid (Fig. 3a) (b) Vegetation community map.

The podzol vegetation is usually woodland or open-forest and is often taller than the trees on the surrounding soils. The tree species common to both sites, *Angophora costata* and *Eucalyptus gummifera*, are usually important components on sandstone podzols over most of the Sydney region. The third species, although frequently *Eucalyptus piperita*, is less constant. The understorey species restricted to the two podzols, *Ceratopetalum gummiferum, Xylomelum pyriforme, Xanthorrhoea arborea* and to a lesser extent *Ricinocarpos pinifolius* and *Gompholobium latifolium*, are typical podzol species. *Banksia serrata* is often an obvious species on podzols and was present at both sites. Other species may be locally important.

The important species on these podzols are usually plants with a wide habitat range, or are those which occur on the upper and middle gully slopes. *C. gummiferum* thrives in the damper gullies (Rotherham *et al.*, 1975) but it is also found in three situations on and near the plateaux surface. The first is the rocky positions, either along creeks incised a few metres below the immediate plateau surroundings, or on the sheltered sides of rock outcrops. The second situation is the deep sand bodies, most of which have podzol soils, where rock outcrops are noticeably absent. Thirdly, *C.*

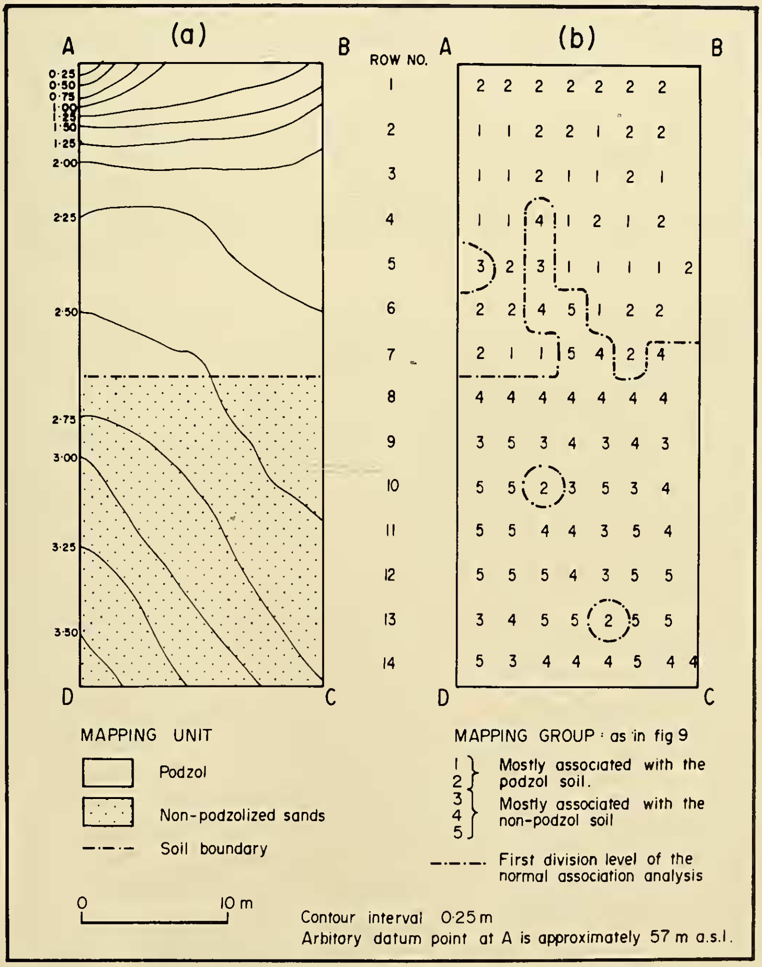

Fig. 11. Site B. (a) Soil and microtopography of the sample grid (Fig. 5a) (b) Vegetation community map.

gummiferum is sometimes found on more clayey soils, either derived from occasional intercalations of shale, or associated with the boundary between Hawkesbury Sandstone and the overlying Wianamatta shale, such as along Mona Vale Road between the junctions with Forest Way and McCarrs Creek Road (Fig. 1).

On the Hornsby Plateau *X. arborea* and *G. latifolium* are most frequent on upper and middle slopes, while the very common *B. serrata* has a wide habitat range, as do the less common *X. pyriforme* and *R. pinifolius*. Other common species on podzols include the habitat-tolerant *Leptospermum attenuatum* and *Dillwynia retorta* and the slope species *Smilax glyciphylla* and *Platylobium formosum*.

This assemblage of species may also occasionally be found on sand deposits some of which may have a considerable clay component but no development of a podzol profile. In general, however, a combination of topographic situation (low slope) and floristics may be used to locate podzols.

Grevillea species have rarely been recorded on the main body of a podzol. The absence of this genus is one of the most unexpected features, as twenty species with a wide range of habitats occur in the Sydney region (Beadle, Evans and Carolin, 1972). One of these species, *Grevillea linearifolia*, is a very common plant of the gully slopes on the Hornsby Plateau. In this situation it frequently grows with *C. gummiferum*. No *Grevillea* species were recorded on the podzol at Site A, although two species grew on the adjacent soil. At the Site B podzol, *G. linearifolia* and *G. buxifolia* grew only on the steeper slope adjacent to the creek.

Many species common in the heaths and low woodland on the plateau are infrequent on podzols, even though the podzols may immediately adjoin such communities. The very common plateau tree, *Eucalyptus haemastoma*, has rarely been recorded, while shrub species uncommon on the podzol include *Banksia aspleniifolia, Gompholobium grandiflorum, Angophora hispida* and the *Grevillea* species.

Because the podzol vegetation has greatest affinity with the gully slope vegetation and very little with the plateau vegetation, podzols on the plateau are easier to locate than those in the gullies. In plateau areas the extent of the podzol can be roughly mapped by the distribution of the easily observed *C. gummiferum* which is usually the most conspicuous species on these podzols even where it is not common. It is a tall slender plant (average heights of 2.5 m and 3.5 m at Site A and Site B) and stems up to 4 m tall are present on both podzols. On the podzols, *C. gummiferum* is usually multi-stemmed and the dense, light green leaves are often present from near ground level. This tall dense mass contrasts sharply with the sparser, grey-green xeromorphic foliage of most species. Although the average height of vegetation on the podzol and non-podzol at each site was similar (1.5 m and 1.0 m at Site A and 2.5 m at Site B; Tables 2 and 3), the presence of this tall dense mass of *C. gummiferum* foliage usually makes the vegetation on the podzols appear taller than the surrounding vegetation.

On the podzols *R. pinifolius* and *G. latifolium* are fairly inconspicuous, thin-stemmed shrubs rarely more than 2 m tall. *B. serrata* may be a small tree up to 4-5 m tall but the average height of this thick-stemmed species was only 1-1.5 m. *X. arborea* is a fairly obvious member, as individuals with stems up to 2 m tall are often present. *Xylomelum pyriforme* is usually present but is always uncommon.

The podzol vegetation is a fairly stable unit, as all of the six indicator species regenerate from parent plants after fire. *C. gummiferum* often has a clumped distribution as it usually possesses a well-developed lignotuber, especially in fire-prone areas such as the plateau surface. The lignotuber of one plant may be almost as large as the 2 m^2 quadrat used. Small *B. serrata* and *X. pyriforme* regenerate from lignotubers, but larger plants usually regenerate from epicormic buds on the main stem. *R. pinifolius* and perhaps *G. latifolium* regenerate from underground perennating buds and are clumped on a much smaller scale than *C. gummiferum*. *X. arborea* continues growing from its apical meristem and all the trees regenerate from lignotubers or epicormic buds after fire.

This paper unlike that of Enright (1978) does not deal with important general issues such as the genesis of podzol soils, the origin of the characteristic vegetation or the interaction between vegetation and soils. Nevertheless we would like to consider briefly two possible causes of the different vegetation between podzols and non-podzol soils. The different distribution of plants on soils with essential chemical differences is well documented. Thus in the field situation dealt with by Enright (1978) both calcareous and non-calcareous parent materials occurred, with podzols, and hence podzol vegetation, best developed on the non-calcareous aeolian sands. Such a dramatic difference in soil chemistry is not likely at Sites A and B as the acidic parent material of the podzol and non-podzol is all derived from the Hawkesbury Sandstone. However, at Sites A and B there is a difference in soil drainage characteristics between the podzol and the non-podzol. The podzol has a well-aerated and well-drained layer overlying a less pervious pan that may also act as a perched water table. In comparison, the non-podzol is a less well drained soil. This contrast may explain some of the differences in the vegetation between the podzol and the non-podzol.

Acknowledgements

Our thanks are due to Dr. M. Westoby for criticizing an early draft of this manuscript and Dr. D. A. Adamson, School of Biological Sciences, Macquarie University; to Mr. T. R. Paton, Mr. P. B. Mitchell and the cartographic staff, School of Earth Sciences, Macquarie University; Dr. R. Outhred, Institute of Technology, N.S.W.; and the Royal Botanic Gardens of N.S.W.

References

Beadle, N. C. W., Evans, O. D., and Carolin, R. C., 1972. — *Flora of the Sydney Region*. Sydney: A. H. & A. W. Reed.

Buchanan, R. A., 1980. — The Lambert Peninsula, Ku-ring-gai Chase National Park. Physiography and the distribution of podzols, shrublands and swamps, with details of the swamp vegetation and sediments. *Proc. Linn. Soc. N.S.W.* 104: 73-94.

Bureau of Meteorology, 1948. — *Results of Rainfall Observations made in N.S.W.* Section I-VI, Commonwealth of Australia.

——, 1975. — *Climatic Averages Australia Metric Edition,* Dept. Science and Consumer Affairs. Canberra. Australian Government Publishing Service.

Burges, A., and Drover, D. P., 1953. — The rate of podzol development in the sands of the Woy Woy district, New South Wales. *Aust. J. Bot.* 1: 4-94.

Burrough, P. A., Brown, L., and Morris, E. C., 1977. — Variations in vegetation and soil patterns across the Hawkesbury Sandstone plateau from Barren Grounds to Fitzroy Falls, New South Wales. *Aust. J. Ecol.* 2: 137-159.

Curtis, J. T., and McIntosh, R. P., 1950. — The inter-relations of certain analytic and synthetic phytosociological characters. *Ecology* 31: 434-455.

Dixon, W. J., (ed.), 1973. — *BMD Biomedical Computer Programs*. Los Angeles: University of California Press.

Enright, N. J., 1978. — The interrelationships between plant species distribution and properties of soils undergoing podzolization in a coastal area of S.W. Australia. *Aust. J. Ecol.* 3: 389-401.

Forster, G. R., Campbell, D., Benson, D., and Moore, R. M., 1977. — *Vegetation and soils of the western region of Sydney,* pp. 53. CSIRO Division of Land Use Research. Tech. Memo 77/10. Canberra.

Hamilton, G. J., 1976. — Soil resources of the Hawkesbury River Catchment, New South Wales. *J. Soil Conserv. Serv. N.S.W.* 22: L 204-229.

Kershaw, K. A., 1973. — *Quantitative and Dynamic Plant Ecology*. London: Edward Arnold.

NORTHCOTE, K. H., 1974. — *A factual Key for the Recognition of Australian soils.* 4th ed. Glenside, South Australia: Rellim Technical Publications.

PATON, T. R., 1978. — *The Formation of Soil Material.* London: George Allen & Unwin Ltd.

PIDGEON, I. M., 1937. — The ecology of the central coastal area of New South Wales. I. The environment and general features of the vegetation. *Proc. Linn. Soc. N.S.W.* 62: 315-340.

——, 1938. — The ecology of the central coastal area of New South Wales. II. Plant succession on the Hawkesbury Sandstone. *Proc. Linn. Soc. N.S.W.* 63: 1-26.

——, 1941. — The ecology of the central coastal area of New South Wales. IV. Forest types on soils from the Hawkesbury Sandstone and Wianamatta Shale. *Proc. Linn. Soc. N.S.W.* 66: 113-137.

ROTHERHAM, E. R., BLAXELL, D. F., BRIGGS, B. G., and CAROLIN, R. C., 1975. — *Flowers and Plants of New South Wales and Southern Queensland.* Sydney: A. H. & A. W. Reed.

SPECHT, R., 1970. — Vegetation. *In* G. W. Leeper (ed.), *The Australian Environment.* 4th ed. Melbourne: CSIRO & Melbourne University Press.

STACE, H. C. T., HUBBLE, G. D., BREWER, R., NORTHCOTE, K. H., SLEEMAN, J. R., MULCAHY, M. J., and HALLSWORTH, E. G., 1968. — *A Handbook of Australian Soils.* Glenside, South Australia: Rellim Technical Publications.

WALKER, P. H., 1960. — A soil survey of the County of Cumberland, Sydney Region, New South Wales. *Soil Surv. Unit Dept. Agric. N.S.W., Bull.* 2: 7-109.

——, and HAWKINS, C. A., 1957. — A study of river terraces and soil development on the Nepean River, N.S.W. *J. Proc. R. Soc. N.S.W.* 91: 67-84.

WILLIAMS, W. T., 1976. — Hierarchical divisive strategies. *In* W. T. Williams (ed.), *Pattern Analysis in Agricultural Science.* Melbourne: CSIRO & Elsevier Scientific Publishing Company.

APPENDIX I

The soils were mapped as layers and described in terms of field texture, matrix fabric, planar void development, consistency (as defined in Paton, 1978), Munsell colours, pH and nature of the boundaries (as defined in Northcote, 1974). Two "Type Profiles" (Paton, 1978), one of a podzol and the other of a non-podzol, are described from the vegetation sample area at Site B. These soils were also classified into "Great Soil Groups" (Stace *et al.*, 1968) and "Principal Profile Forms" (Northcote, 1974).

There is a sharp boundary of less than 2 m between these two soil types and the intravariation is small.

Type Profile:	Podzol
Great Soil Group:	Podzol
Principal Profile Form:	Uc 2.3, approx. Uc 2.36
Location:	Site B; centre of the podzol half of the sampling grid (Figs. 5 & 11).
Parent Material:	One to 2 m of sand deposits with some cobbles overlying 2 m of *in situ?* altered sandstone.
Vegetation:	Shrubs of *Ceratopetalum gummiferum, Dillwynia retorta, Xanthorrhoea media* and a nearby dead stump of *Eucalyptus gummifera?* and other typical podzol vegetation.
Description:	
2-0 cm (leaf litter)	Leaf litter of the above-mentioned species, especially *Ceratopetalum gummiferum* and *Xanthorrhoea media*; white fungi hyphae connecting many leaves; sharp even to:
0-21 cm pH 5.0-5.5	Organic-rich coarse sand (silky feel); 2.5Y2/1 (dry and moist); single grain sand with minor coherence from the dense root mat; no planar voids; apedal and fragile consistency; abundant charcoal; earthworms in the upper 10 cm, white Scarabaeidae grub in the lower, diffuse wavy to:
21-64 cm (bleached layer) pH 6.0-6.5	Coarse sand; 10YR7/1 (dry), 6/2 (moist); incoherent single grain sand; no planar voids; apedal and very fragile consistency; roots are sparsely distributed and are mainly confined to the upper 15 cm; small patches of fungi hyphae linking individual sand grains in lower 10-20 cm; sharp wavy to:
64-70 cm (organic pan)	Coarse loamy sand; 10YR3/4 (dry), 4/3 (moist); mottled with 10YR2/3 (dry and moist); matrix fabric, weakly coherent, non-uniform and highly porous; planar voids are absent; consistency, apedal and brittle when dry; small patches of fungi hyphae binding individual grains; within and beneath a decaying root (5-7 cm diameter) it is 10YR2/3; sharp irregular to:

70-89 cm (iron pan) pH 6.0 — Coarse loamy sand; 10YR 4/4 (dry), 3/4 (moist) with mottles of 10YR 5/6 (dry), 4/6 (moist); matrix fabric, moderately coherent, non-uniform and very porous; no planar voids; consistency, apedal and brittle when dry. Interspersed are mottles of 7.5 YR 5/8 (dry & moist); matrix fabric, very coherent non-uniform and porous with no planar voids in the upper part of the layer but it is very nodular in the lower half; consistency, brittle and very indurated when dry requiring considerable pressure to disrupt. Charcoal throughout often centering the very indurated material; earthworms and termites present:

89-100 cm pH 5.5 — Coarse clayey sand; 10YR 5/8 (dry & moist); matrix fabric, moderately coherent, non-uniform; no planar voids; consistency, slightly plastic; some charcoal and few roots.

Type Profile: Depositional Earth

Great Soil Group: Earthy Sand

Principal Profile Form: Gn 2.21 to Um 5.22

Location: Site B, near centre of the non-podzol half of the sampling grid (Figs 5 & 11).

Parent Material: Approximately 0.5 m of sand deposits overlying more than 1 m of *in situ?* altered bedrock.

Vegetation: Small tree of *Persoonia levis* and shrubs of *Banksia marginata, Dillwynia retorta, Leptospermum attenuatum* and *Platysace linearifolia*, and other typical non-podzol vegetation.

Description:

1.0 to 0 cm — Thin litter layer, mainly of leaves from *Persoonia levis;* sharp even to:

0-8 cm pH 5.0 — Coarse sand; 2.5Y 4/2 (dry), 5/2 (moist); highly porous, sand-dominated, non-uniform, fragile matrix fabric, with added but weak coherency due to the organic matter; no planar voids; consistency apedal and very brittle; roots throughout; plenty of coarse charcoal; grub (Scarabaeidae) present; clear, even to:

21-50 cm pH 5.0 — Medium sandy loam; 10YR 5/5 (dry and moist); porous, sand-dominated, non-uniform and coherent matrix fabric with indurated nodules 10YR 4/6 (dry and moist) of weakly porous to dense, sand-dominated, non-uniform and very coherent matrix fabric; no planar voids; consistency apedal and brittle; fine charcoal; some white quartz pebbles one to 1.5 cm diameter; few large roots; gradual even to:

50-180 cm pH 5.5-6.0 — Clayey sand 10YR 5/8 (dry and moist); moderately porous clay-dominated, non-uniform and coherent matrix fabric; no planar voids; slightly subplastic consistency; occasional white quartz pebble one to 1.5 cm diameter. In lower 1 m (augered) mottled streaks of 7.5 YR 5/8 dry and moist occur.

APPENDIX II

Species mentioned in paper

GYMOSPERMAE

Podocarpaceae:

Podocarpus spinulosus (Sm.) R. Br. ex Mirb.

ANGIOSPERMAE

Dicotyledones

Proteaceae:

Banksia aspleniifolia Salisb.
B. ericifolia L.f.
B. marginata Cav.
B. robur Cav.
B. serrata L.f.
B. spinulosa Sm.
Conospermum longifolium Sm. ssp. *longifolium*

Grevillea buxifolia (Sm.) R. Br.
G. linearifolia (Cav.) Druce
G. sericea (Sm.) R. Br.
Hakea dactyloides (Gaertn.) Cav.
H. gibbosa Cav.
H. teretifolia (Salisb.) J. Britt.
Lambertia formosa Sm.
Lomatia silaifolia (Sm.) R. Br.
Persoonia lanceolata Andr.
P. levis (Cav.) Domin
P. Unnamed
Petrophile pulchella (Salisb.) Knight
Xylomelum pyriforme Sm.

Dilleniaceae:
Hibbertia linearis DC. var. *obtusifolia*
H. sp.

Euphorbiaceae:
Ricinocarpos pinifolius Desf.

Cunoniaceae:
Ceratopetalum gummiferum Sm.

Mimosaceae:
Acacia terminalis (Salisb.) MacBride
A. myrtifolia (Sm.) Willd.
A. suaveolens (Sm.) Willd.
A. ulicifolia (Salisb.) Court

Papilionaceae:
Bossiaea heterophylla Vent.
Dillwynia retorta (Wendl.) Druce var. *retorta*
Gompholobium grandiflorum Sm.
G. latifolium Sm.
Phyllota phylicoides (Sieb. ex DC.) Benth.
Platylobium formosum Sm.
Pultenaea elliptica Sm.
P. stipularis Sm.

Myrtaceae:
Angophora hispida (Sm.) Blaxell
A. costata (Gaertn.) Druce
Eucalyptus globoidea Blakely
E. gummifera (Gaertn.) Hochr.
E. haemastoma Sm.
E. oblonga DC
E. piperita Sm. ssp. *piperita*
E. sieberi L. Johnson
E. sp.
Kunzea capitata Reichb.
Leptospermum attenuatum Sm.
L. flavescens Sm.
L. squarrosum Sol. ex Gaertn.

Rutaceae:
Eriostemon australasius Pers.
Boronia ledifolia (Vent.) J. Gay
B. pinnata Sm.

Sapindaceae:
Dodonaea triquetra Wendl.

Umbelliferae:
Platysace linearifolia (Cav.) C. Norman

Epacridaceae:
Epacris pulchella Cav.
Epacridaceae sp.
Leucopogon ericoides (Sm.) R. Br.
L. microphyllus R. Br.
Woollsia pungens (Cav.) F. Muell.

Monocotyledones
- Xanthorrhoeaceae:
  - *Xanthorrhoea arborea* R. Br.
  - *X. media* R. Br. ssp *media*
- Cyperaceae:
  - *Gahnia sieberana* Kunth
- Restionaceae:
  - *Empodisma minus* (Hook.f) Johnson & Cutler syn. *Calorophus minor* Hook.f

The species names are those currently used by the Royal Botanic Gardens of N.S.W. (1978).